Health Care Aboard the *Hokulea*—Energy Requirement Study

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The Hokulea was designed and built as an archaeological experiment to test the theory of "intentional exploration and colonization of Polynesia as opposed to the theory of accidental settlement." It is a 60-foot replica of an early Polynesian voyaging canoe. First launched in the spring of 1975, the Hokulea has made multiple voyages between Hawaii and Tahiti navigated without the use of instruments of any kind. The Polynesian Voyaging Society is the no-for-profit corporation that built and operates the Hokulea and the Hawaii Loa, a larger double-hulled sailing vessel scheduled for its maiden voyage in 1995.

With the emphasis on authenticity in as many areas as possible, the April 1986 voyage of a traditional Polynesian canoe from the Marquesas to Hawaii was an interesting challenge.

In the area of nutrition, a multitude of factors had to be considered. While striving for traditional authenticity, we had to be alert to the food itself: Preparation, preservation, packaging, palatability, nutritional make-up and value, bulk and weight for storage, and its preparation on the voyage. Consideration of the amount of water needed for its preparation or reconstitution, as in the case of *paiai*, was important because of the limited supply of water carried aboard. Many of these were noted in the draft of the Request for Proposal for the Native Hawaiian Culture and Arts Program of the Bishop Museum.[1]

Consideration of nutrition also required looking at the recipient side of the equation. Only vague glimpses and theories were available to us of the physical stature and make-up of the initial and early Polynesian sailing crews. We like to fantasize them as robust, powerful people in the best of physique and health; in all probability they were much the same as today, albeit physically stronger, more fit, and inured to the sea because of the prevailing lifestyle. I believe, though, that they were physiologically similar to Hawaiians of today.

With this thought in mind, nutritional considerations should make use of some interesting findings gleaned from studies that I made on voyages in 1980 and 1985 to 1987.

During those years, I was the physician on board the majority of the sailing legs. I personally undertook a study to determine the caloric requirements and the calorie expenditure of the crew members. The study was divided into 1) duration of sail, 2) body type of member, 3) racial mix of member, 4) gender, 5) general health status, and 6) age.

The pre-sail weight was logged for each crew member along with his or her vital statistics and demographics. A medical history was obtained; however, no laboratory tests were done.

The total consumption of oral intake for each individual was logged diligently for each 24-hour period. A daily medical log was kept. It should be noted that in this study, seasickness was never a factor. On one 35-day voyage, we attempted to record the weights of all members twice a week. The participation was not 100% on this endeavor; some crew members lacked interest or refused to be weighed, saying it was a "pain in the ass."

Enough information, however, was obtained to make valid projections about weight changes related to time at sea. On completion of a voyage everyone was weighed within 2 hours of landfall and compliance at this stage was excellent, in all occasions nearing the 98th percentile. The same scale used at the onset was used for the closing weights, although at certain isolated areas a different scale had to be used, thereby introducing a factor for error.

The daily oral consumption charts were given to Kathleen Watanabe, then a registered dietitian at G.N. Wilcox Hospital on Kauai. She calculated the total caloric intake per day of each individual in the crew. With the data on weight change by the week and/or the total voyage, a tabulation was made for each individual for positive (weight gain), negative (weight loss) or neutral (no change or minimal change) weight change. Factored into this was the standard figures of caloric requirements for basal body functions and maintenance levels for individuals according to height and weight.

Some interesting findings were noted. The medial 24 hour caloric intake was 4700 calories, the high was 6420 Cal and the low 3680 Cal. The weight change showed a median weight loss of a 30-plus-day voyage as 16.3 lbs loss. The maximum weight loss was 37.5 lbs (MM–Hawaii to Papeete voyage). One individual (ST–Rangiroa to Hilo voyage) had a 4 lb weight gain! In all, 3 individuals gained weight on a 30-day voyage. Of the 3 individuals who gained weight, 2 were thin, well-muscled individuals with estimated body fat of less than 10%; one of the crew members was a woman; two did not have watch duties requiring the heavy work expenditure needed in steering or working the sails; one was a very light eater on board, as he was on land.

Of the people who lost weight, the general correlation could be made that the heavier initial weight and higher percentage of body fat made for greater weight loss. The average daily amount consumed by each individual remained fairly constant during the entire trip, ie, heavy eaters generally ate more, snacked more, and used more peanut butter and jelly on more crackers. But with fair consistency, these individuals had the greater weight loss.

On voyages lasting 12 to 21 days, everyone lost weight, again following the pattern as described above, with a maximum weight loss recorded as 45 lbs in 12 days (JK–Aotearoa to Tongatapu voyage).

Voyages of 7 to 12 days showed moderate weight losses with a maximum of 27 lbs. Even voyages of 3 to 7 days show losses up to 7 lbs but the pattern of +, -, and 0 weight change is erratic. There was no statistically discernible pattern on voyages of 24 hours or less.

In all voyages the daily caloric consumption showed the high levels as described.

From the data and graph, the following assumptions can be made:

- The individual case of MM on a 30-plus-day voyage in which his loss at 21 days was 42 lbs and at voyage end was 37.5 lbs was studied (Fig 1). This pattern was seen on other individuals who could be weighed before, during, and at the end of a voyage. From these figures, it can be assumed that a period of fairly rapid weight loss occurs despite a large caloric intake; a period of leveling off, and a period of gradual regaining of weight.
- During the course of a long voyage, body habitus changes, shoulders broaden, arms enlarge, waists slim down. The loss of body fat and the enlargement of muscle mass is easily seen. I surmise that large amounts of body fat are catabolized during the initial 3 weeks. Thereafter this source of energy is stabilized and as muscle mass increases, weight begins to rise again.
- If an individual required 1500 Cal/day for basal metabolism, the median person with a weight loss of approximately 21 lbs in 3 weeks loses 1 lb/day = 3000 Cal deficit/day. If that individual ate 4000 Cal that day and still lost a pound, he or she had a caloric deficit of 3000 Cal. The total caloric expenditure in energy would be in the range of 7000 Cal/day!

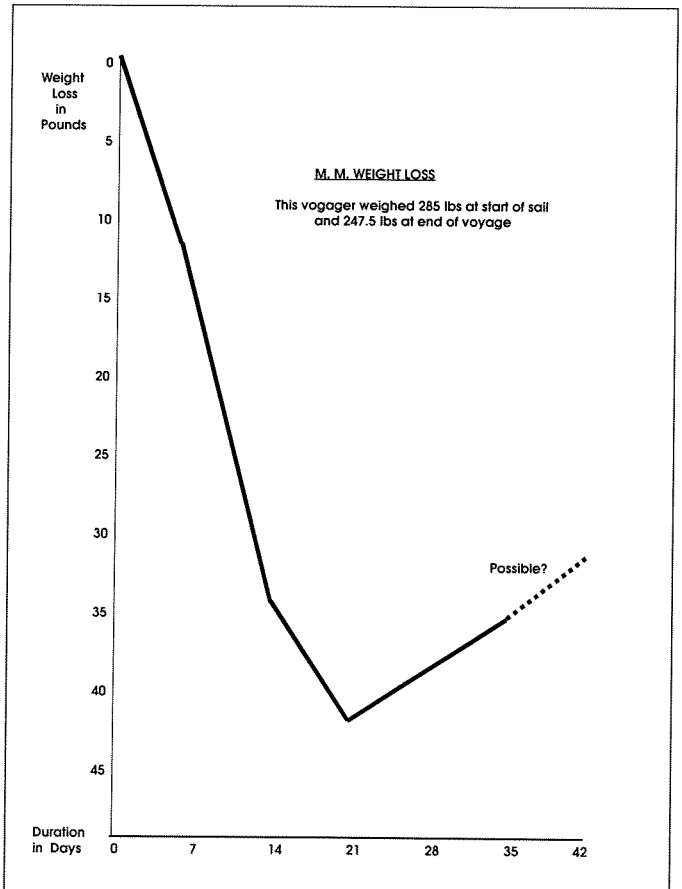

Fig 1.—Crew Member's Weight Loss on a 30-day Plus Voyage.

From these observations the following recommendations can be made:

- Diet should be high in complex carbohydrates (60% to 70%) to:
  - aid in catabolism of fat
  - help in feeling sated
  - protect from ketones and acidosis
- Protein needs can be met with 15% to 20% of diet.
- Fat is needed between 15% to 20% to provide caloric increases.
- Adequate water intake is essential to prevent ketonuria, lactic acidosis and stone formation, particularly in the initial 20 days.
- The most susceptible time for developing illnesses such as colds, flu, and stomach flu would be in the initial 14 to 21 days when rapid tissue breakdown occurs with the possibility of acidosis if water or carbohydrate intake is curtailed.
- The doctor on board should be aware of these parameters so preventive measures can be employed such as dipsticking urine for acidosis and looking for signs of dehydration.
- In reality, the doctor on board would not be able to control an outbreak of flu, cold or enteritis. My belief is preventive precautions to keep any disease process from occurring or spreading is imperative. The physician's recommendation on the adequacy and consumptability of food and water on board should be paramount. He or she should also have responsibility for preventive measures such as a) personal hygiene, b) dental hygiene (brushing, flossing, Stimudent™), c) hygiene of cooking galley and utensils, and most important d) adequate rest periods which would favor a 3 watch system working 4 hours on and 8 hours off.

References

1. Request for proposal; Bishop Museum Native Hawaiian Culture and Arts Program Exploration Program, funded by the National Park Service, Department of the Interior, Grant application September 1, 1994.

Patrick Aiu MD is a gynecologist at Wilcox Memorial Hospital on Kauai and a state surgeon with the Hawaii National Guard. Dr Aiu has been very active in the Polynesian Voyaging Society, serving on its Board of Directors. He also served on the Hokulea *as radio operator, crew member and ship's physician. The voyage he denotes here took place in April 1986, sailing from New Zealand to Tonga.—ED.*